

eRD16: Forward/Backward Tracking at EIC using MAPS Detectors

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Abstract:

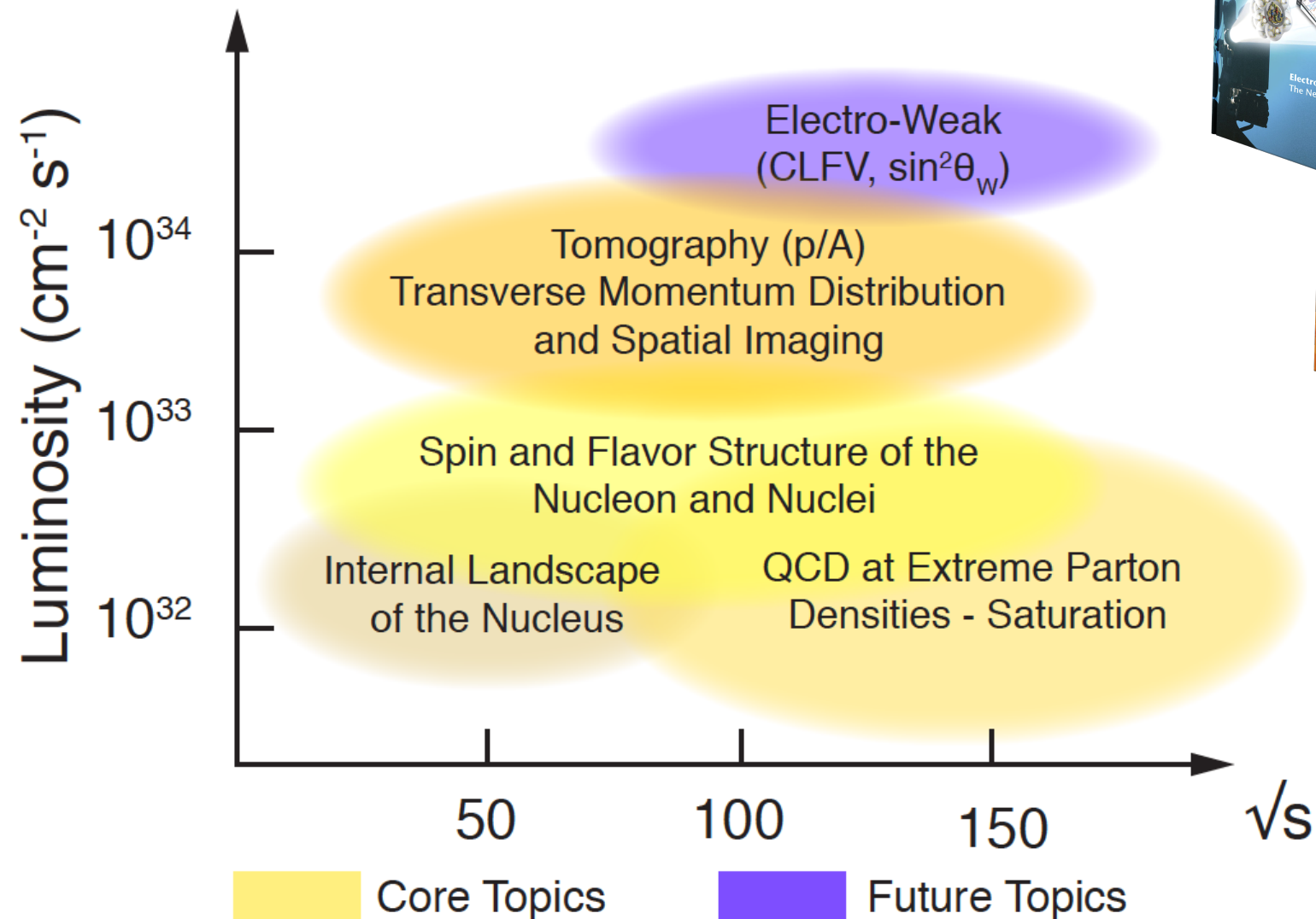
This report describes progress towards the conceptual development of tracking stations with silicon-sensors near the collision vertex to detect the scattered electron and produced secondary hadrons at forward and backward angles in the period between July and December 2016. eRD16 focuses on forward/backward disks of thinned-silicon sensors (MAPS) with the overall goal (extending beyond the current reporting period) of arriving at a layout including concept design for the arrangement of services (cooling, power, and readout) and their integration with central barrel tracking subsystems.

Outline

- Introduction
- Simulations
- Closing comments

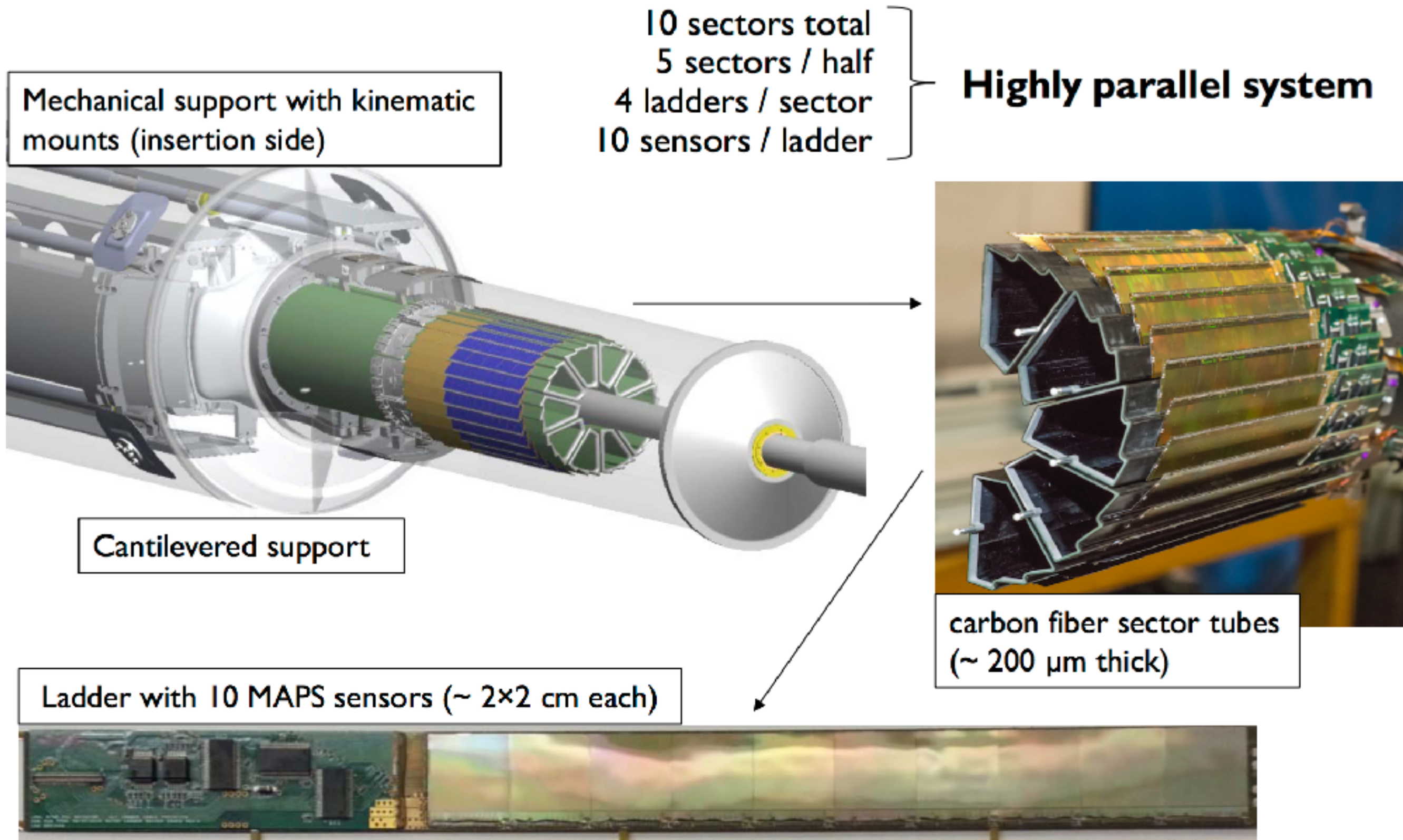
RNC - EIC Physics

Interest in *gluon-dense matter*:



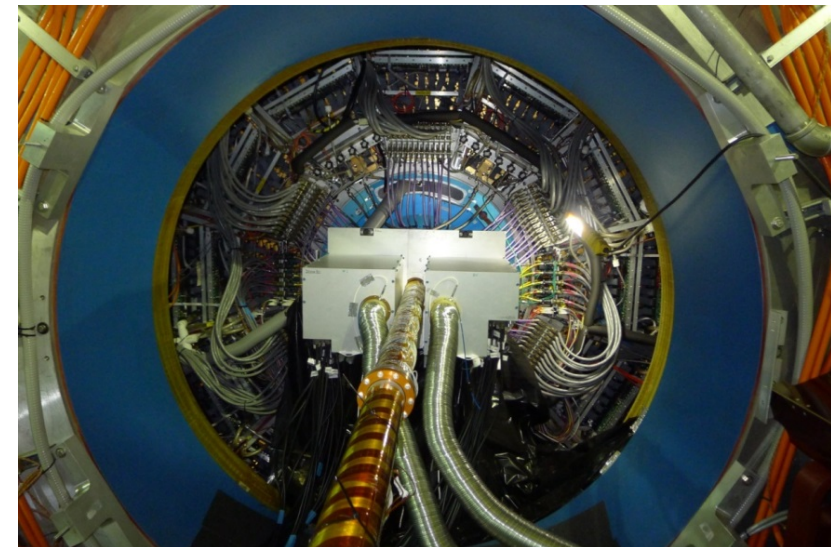
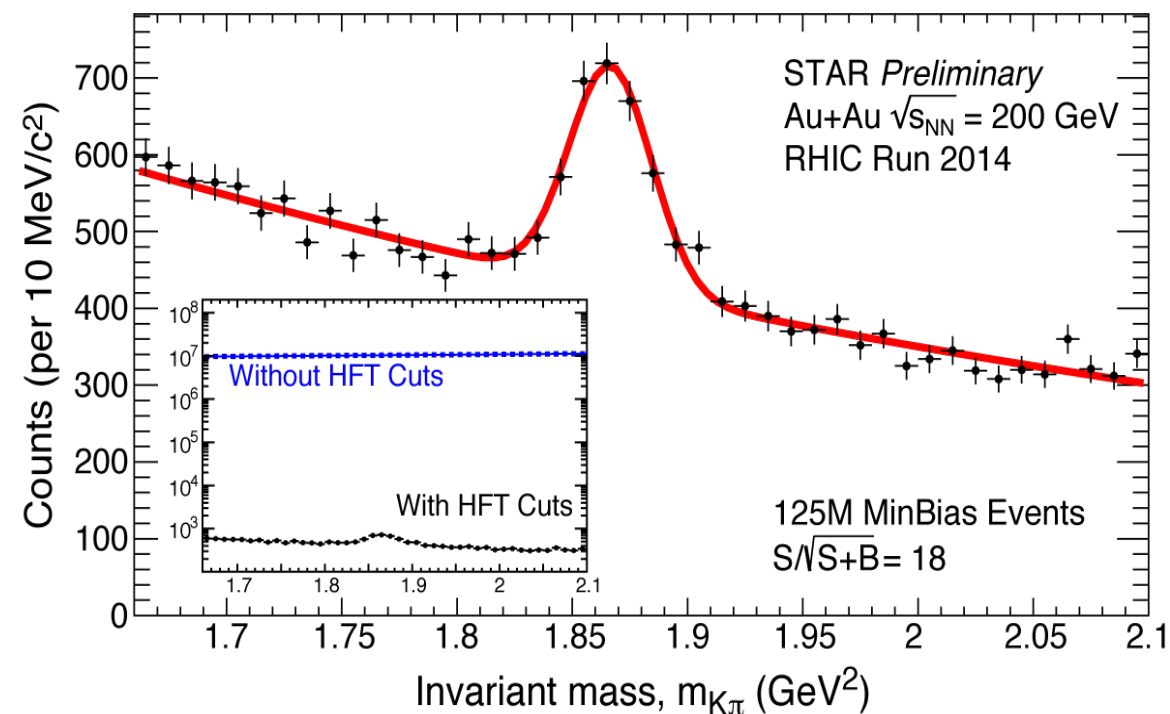
implies a need for *high- \sqrt{s}* ,
 observables $F_2(x, Q^2)$, $F_L(x, Q^2)$, $g_1(x, Q^2)$ at *low- x*
 + diffraction, dijets, heavy flavor, ...³

RNC - STAR HFT-PXL



RNC - STAR HFT-PXL

First large scale MAPS based vertex detector at a collider experiment.



PXL inserted into STAR, cabled and working in 24 hours

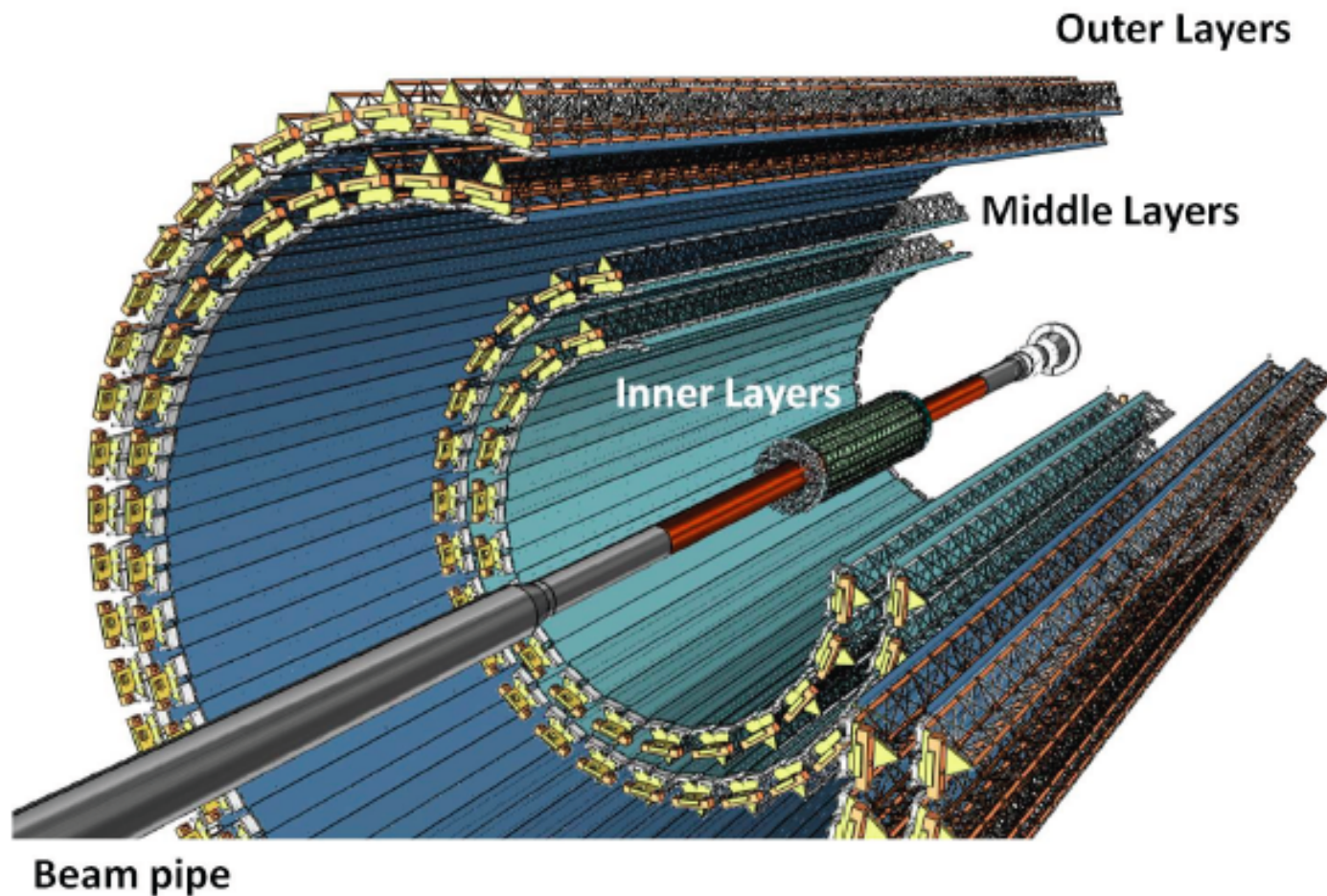
RNC scope:

Full simulation and optimization.

Full system design including R&D into MAPS sensors with IPHC
Strasbourg.

Full construction including RDO electronics, firmware, software,
commissioning and analysis.

RNC - ALICE ITS Upgrade



- 7 layers
- 10 m² of silicon
- Installation in early 2019
- $X/X_0 \sim 0.3\%$ (inner layers)
- $X/X_0 \sim 0.8\%$ (outer layers)

Anticipated use of CERN-developed MAPS sensors, ALPIDE:

Dimensions:	15mm x 30mm
Pixel pitch:	28 μ m x 28 μ m
Integration time:	approx. 4 μ s
Power consumption:	39mW/cm ²

TDR: <http://iopscience.iop.org/0954-3899/41/8/087002/>

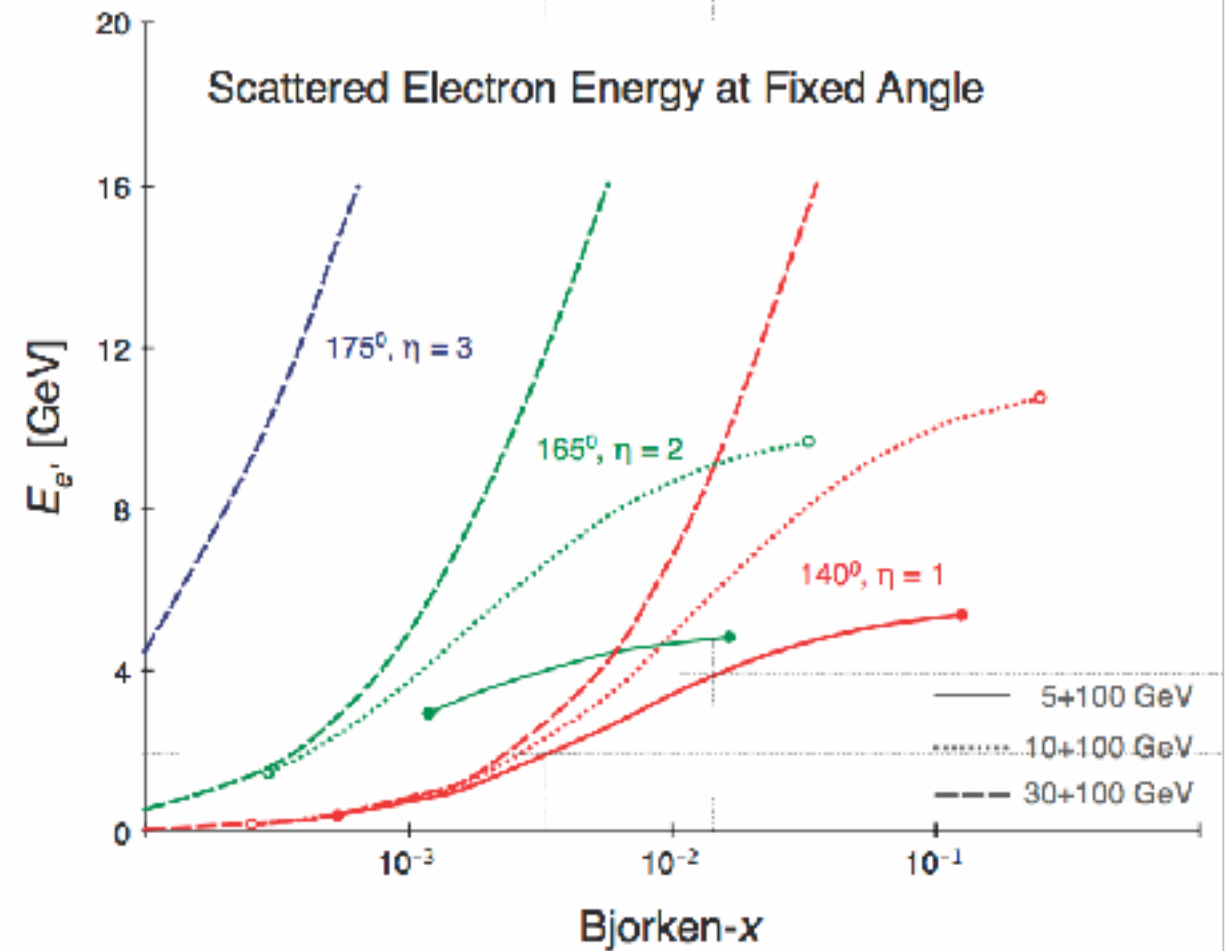
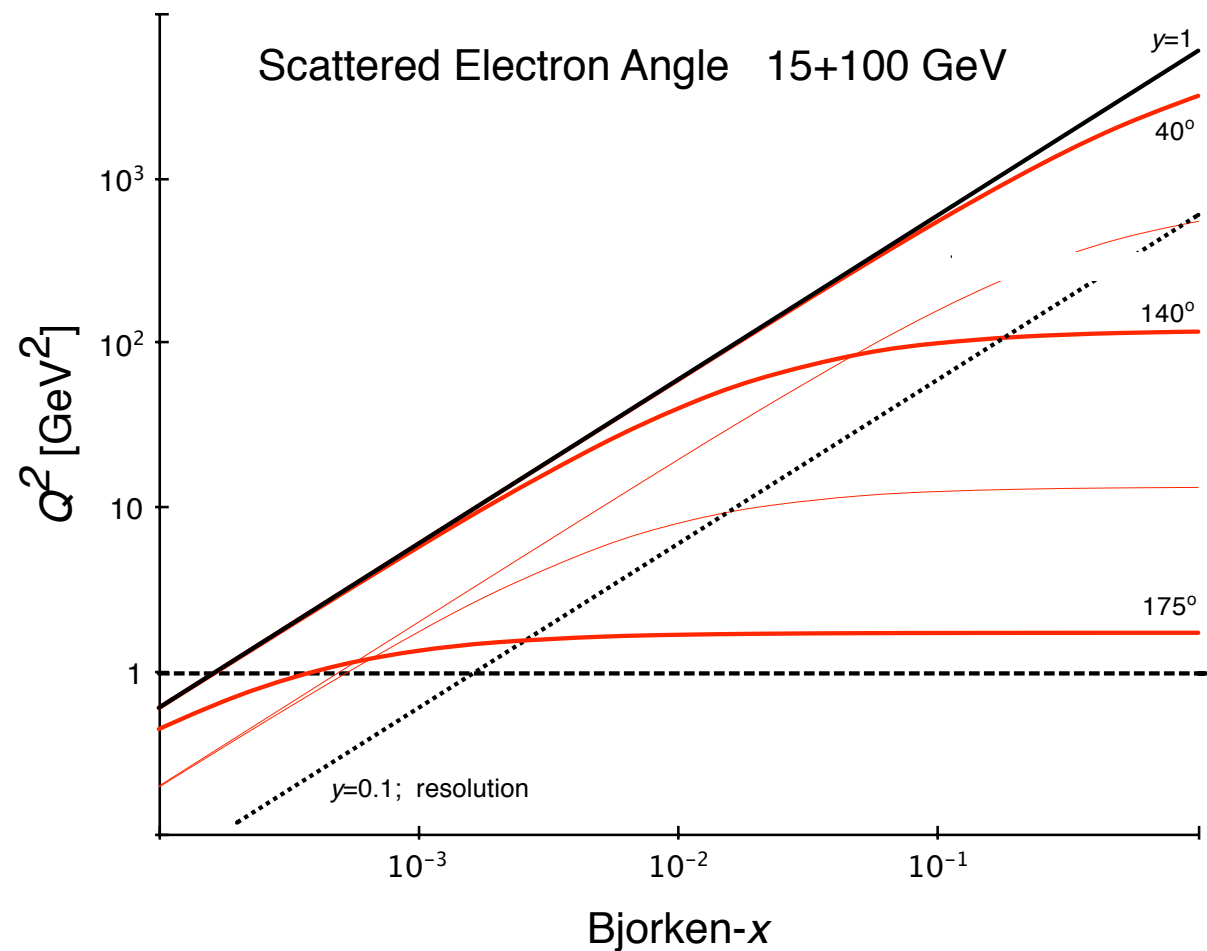
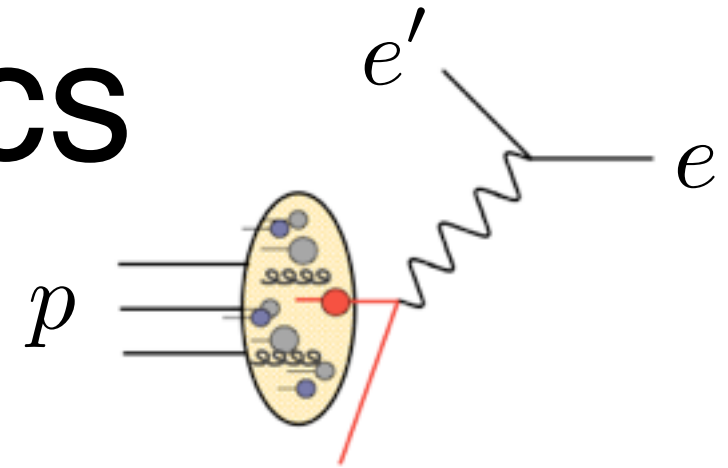
RNC scope:

middle layer staves,
readout & power,
mechanics (with LBL engineering)

Vertex tracker for sPHENIX under discussion/development.

RNC - EIC Physics

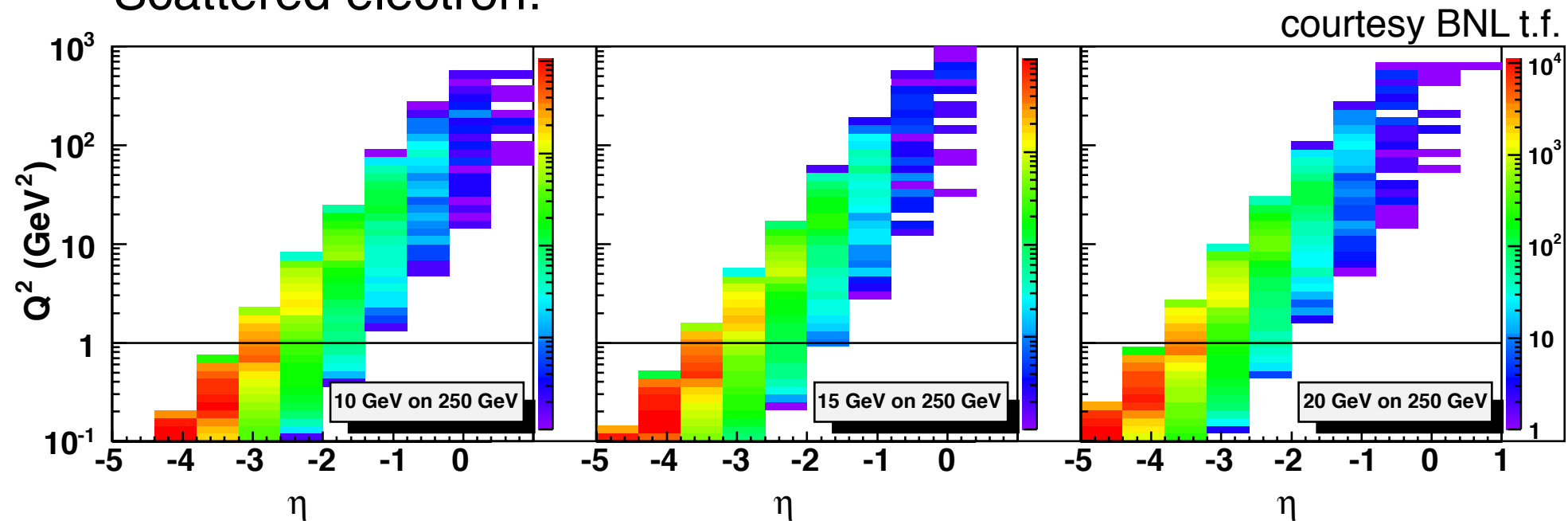
Interest in *gluon-dense matter*:



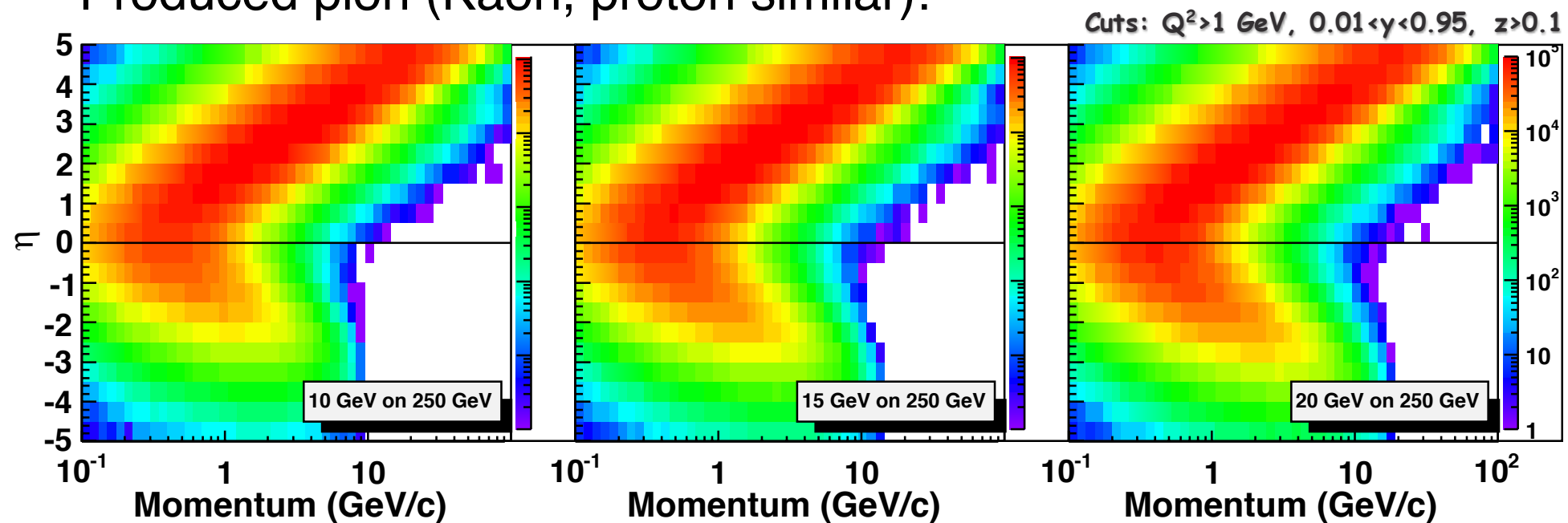
necessitates instrumentation at *backward* angles
w.r.t. the hadron beam (HERA convention)

EIC - DIS particle distributions

Scattered electron:



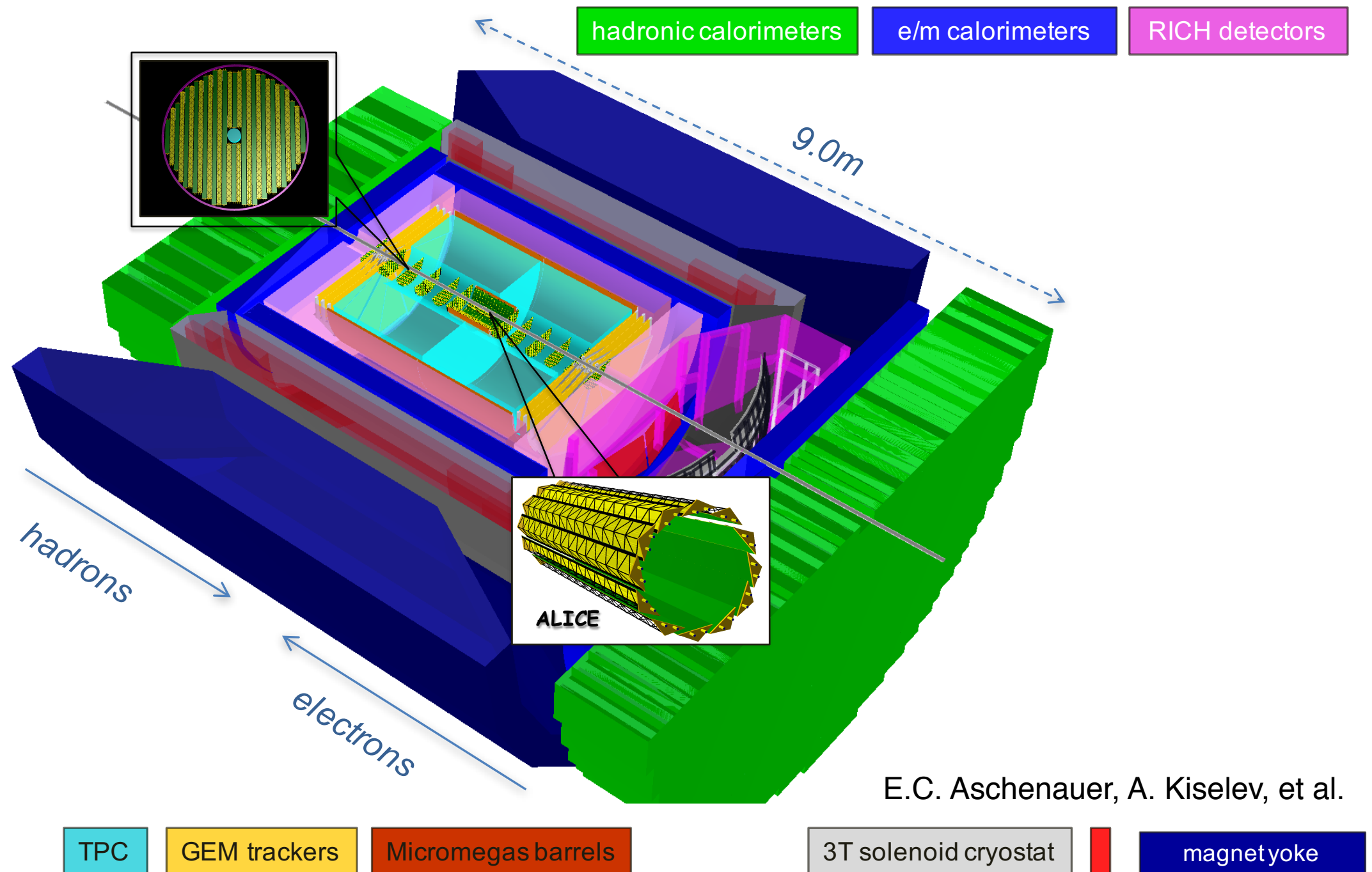
Produced pion (Kaon, proton similar):



and at forward angles w.r.t. the hadron beam.

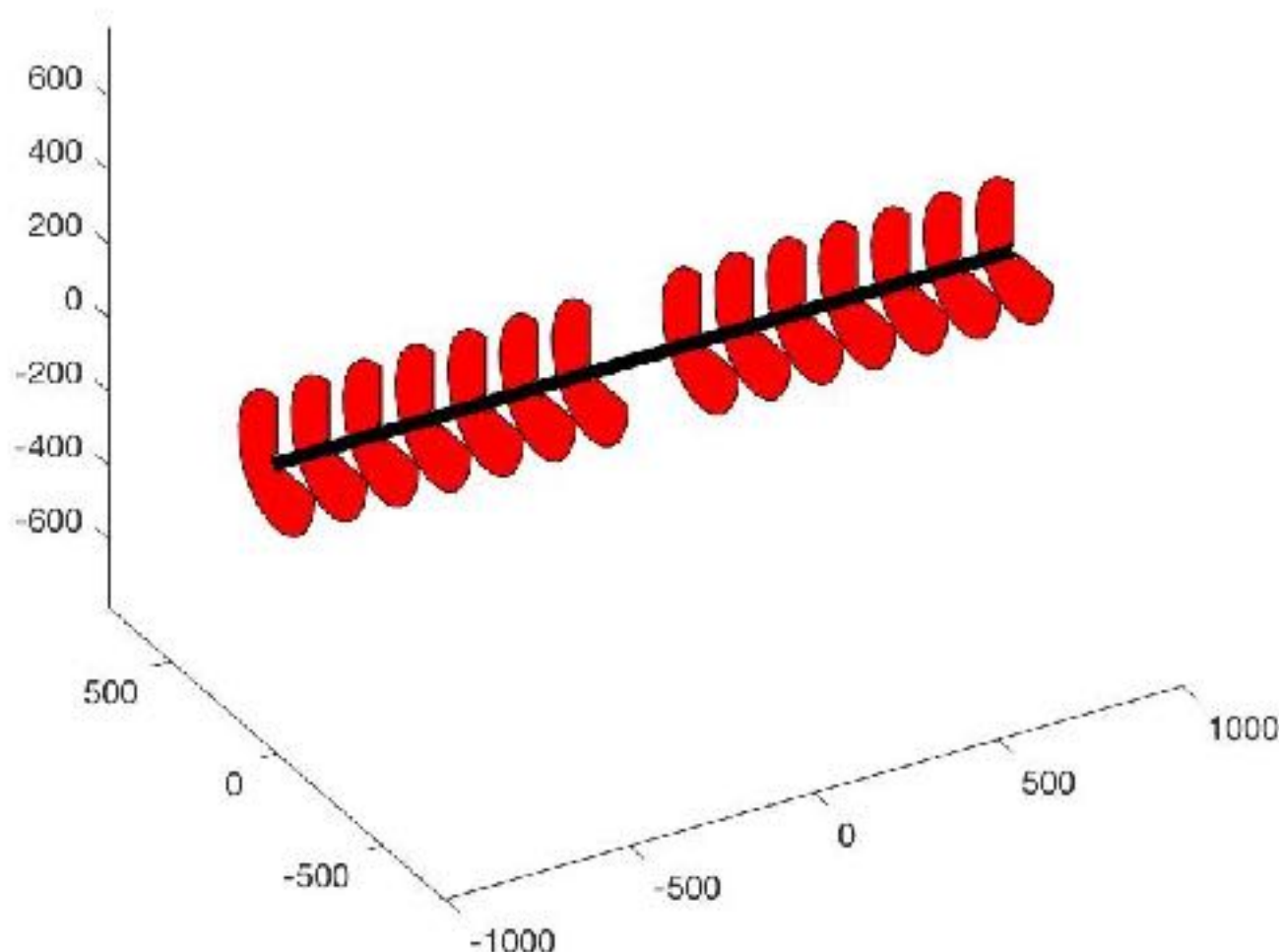
Distributions drive acceptance, PID and other requirements.⁸

eRHIC Model Detector (BeAST)



MAPS-based Si; minimize bremsstrahlung, resolutions, and also vertexing.

Simulations

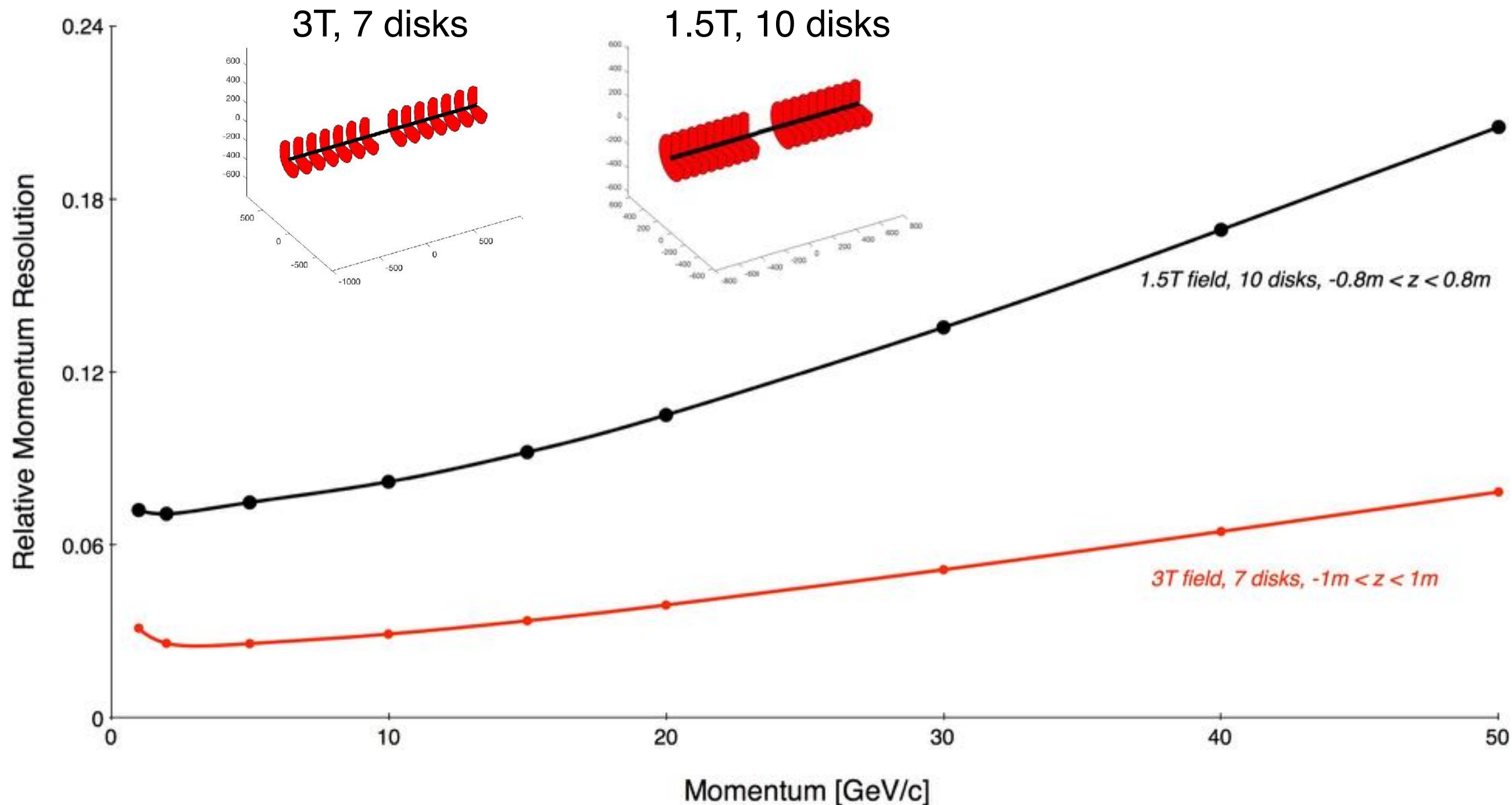


- Tool originally developed for ILC studies (Regler et al, 2008),
- Helix track model,
- Multiple scattering,
- Full track reconstruction from digitized hits using a Kalman filter.

Model of a BeAST-like configuration: 7 equidistant disks, each of $X_0 \sim 0.3\%$ thickness, on either side of the IP in a 3T solenoidal field. 22mm inner disk radius, 180mm outer radius. 1mm thin Be beam-pipe with a 15mm radius.

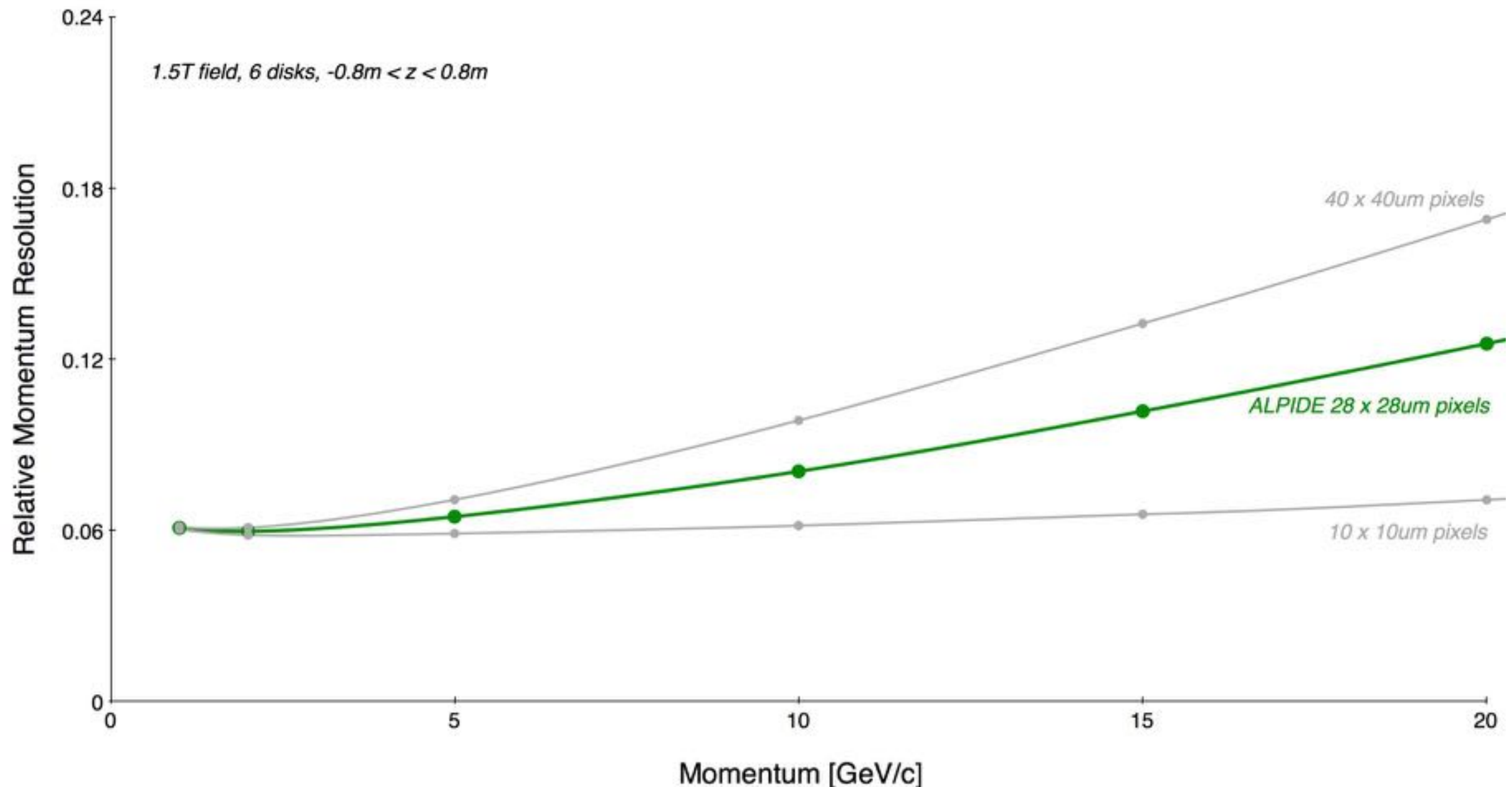
Work done with UCB student Ivan Velkovsky.

Simulations



Results for the 3T BeAST-like configuration establish contact with BNL task-force simulations; then extended to 1.5T. Eta=3 here.

Simulations - Sensor



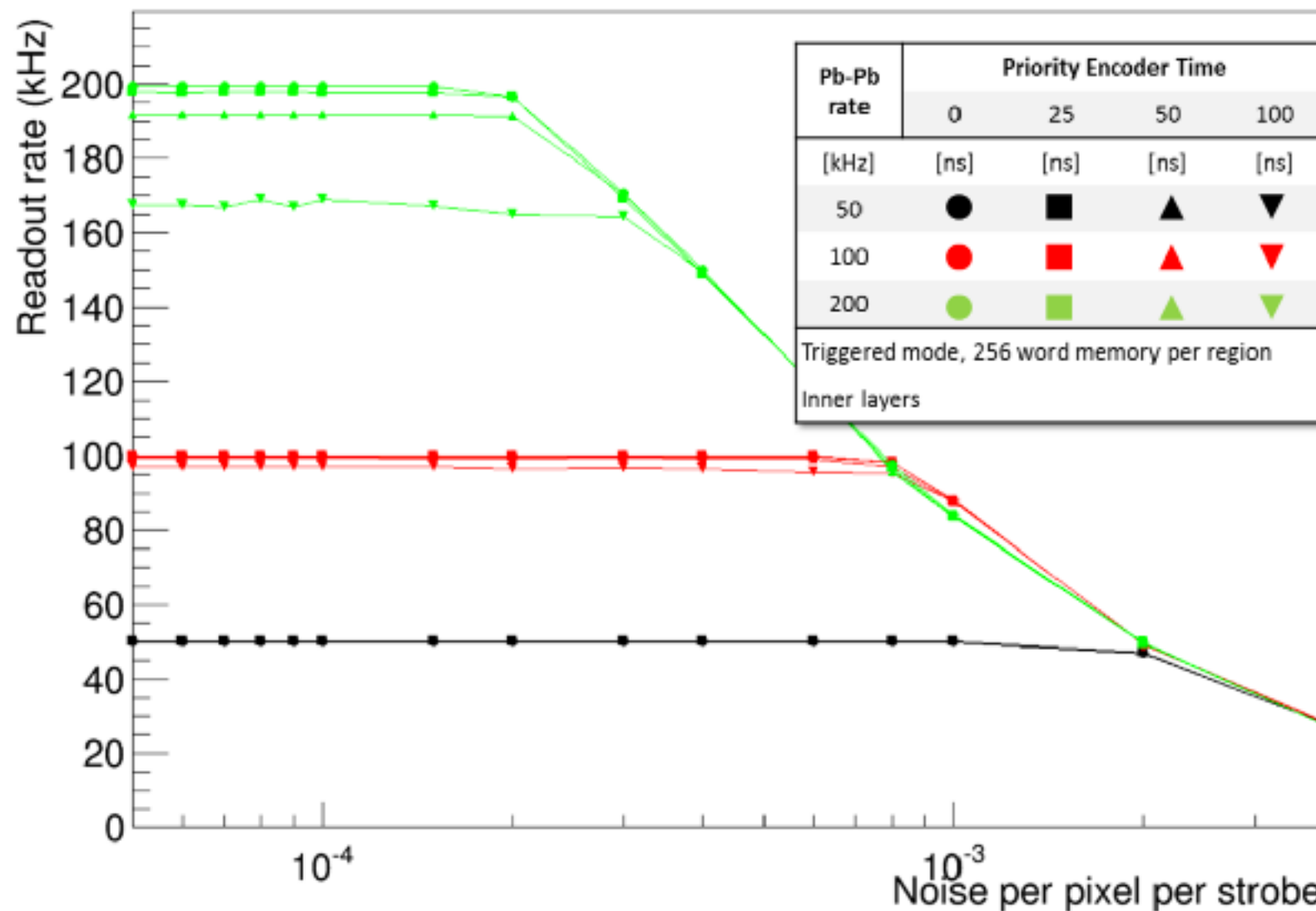
Low-momentum performance is substantially the same for a choice of pixel-sizes in the range of 10x10um to 40x40um (with a realistic beam-pipe).

Continue ALPIDE sensor evaluation for use at EIC.

Work in Progress - Sensor

Integration time of $\sim 4\mu\text{s}$ exceeds EIC bunch-crossing period,

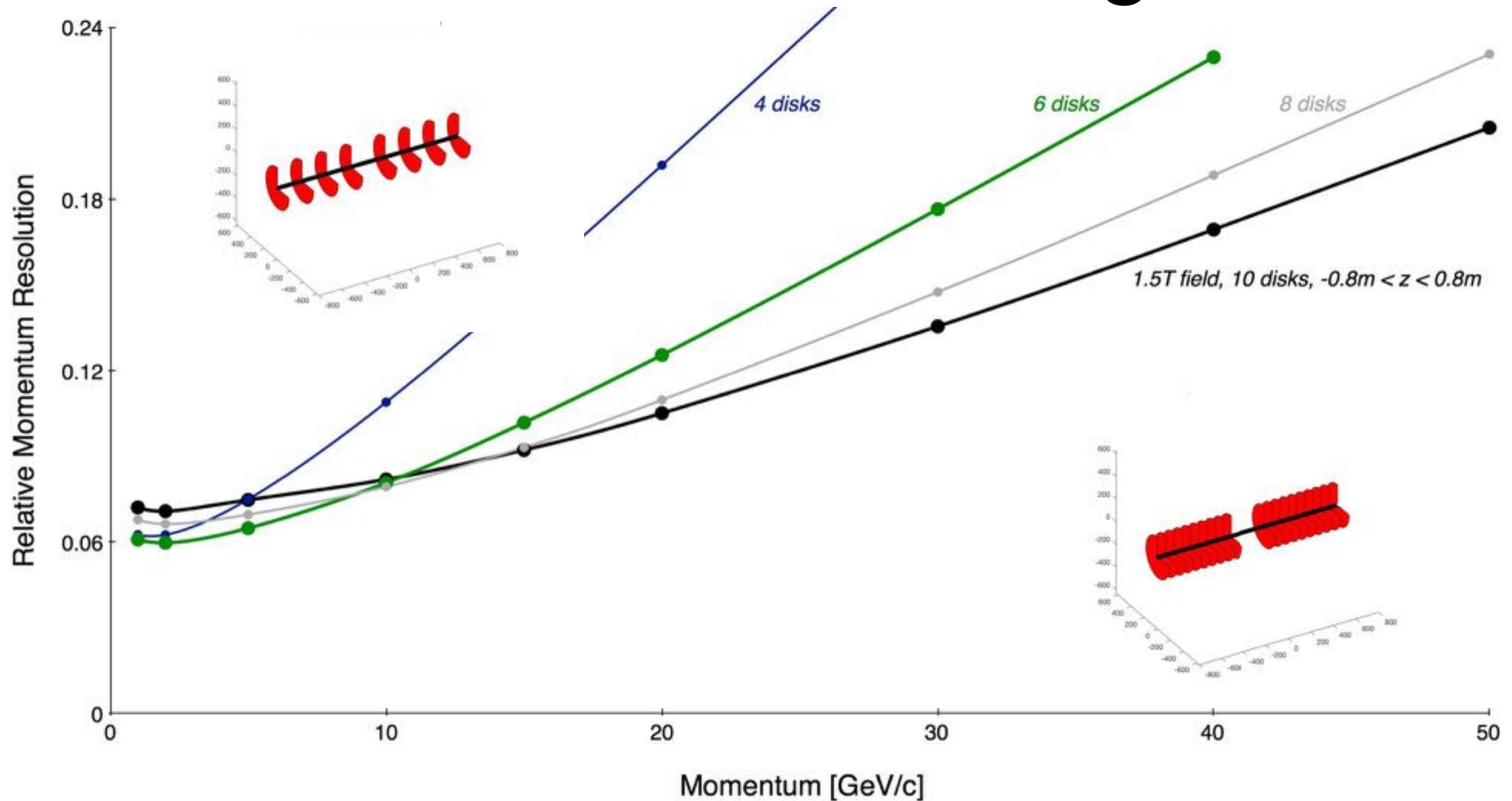
courtesy: ALICE-ITS WP10



Assess rate/noise performance (started),

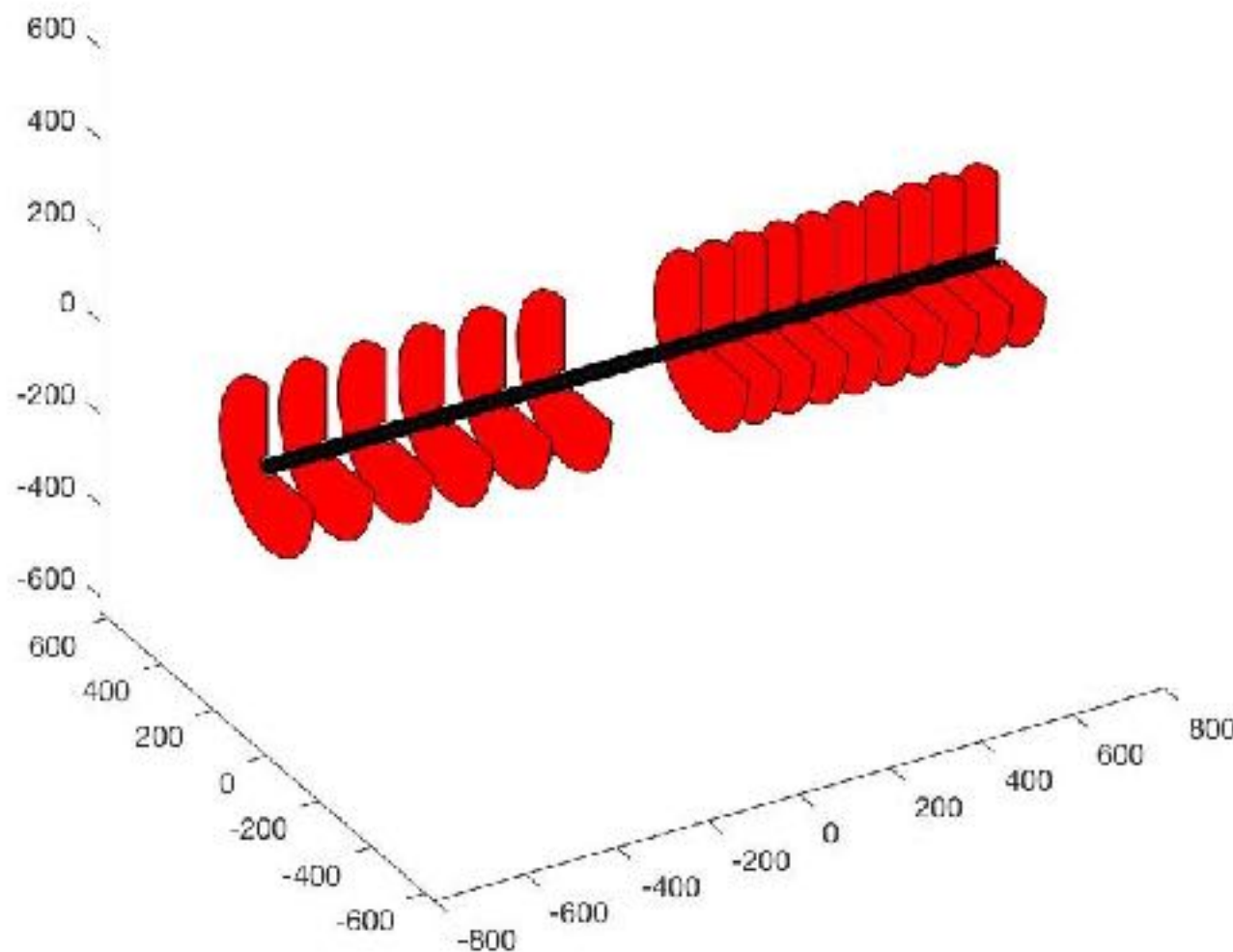
External time-‘anker’, in particular to tag beam-spin configuration.

Simulations - Disk Configuration



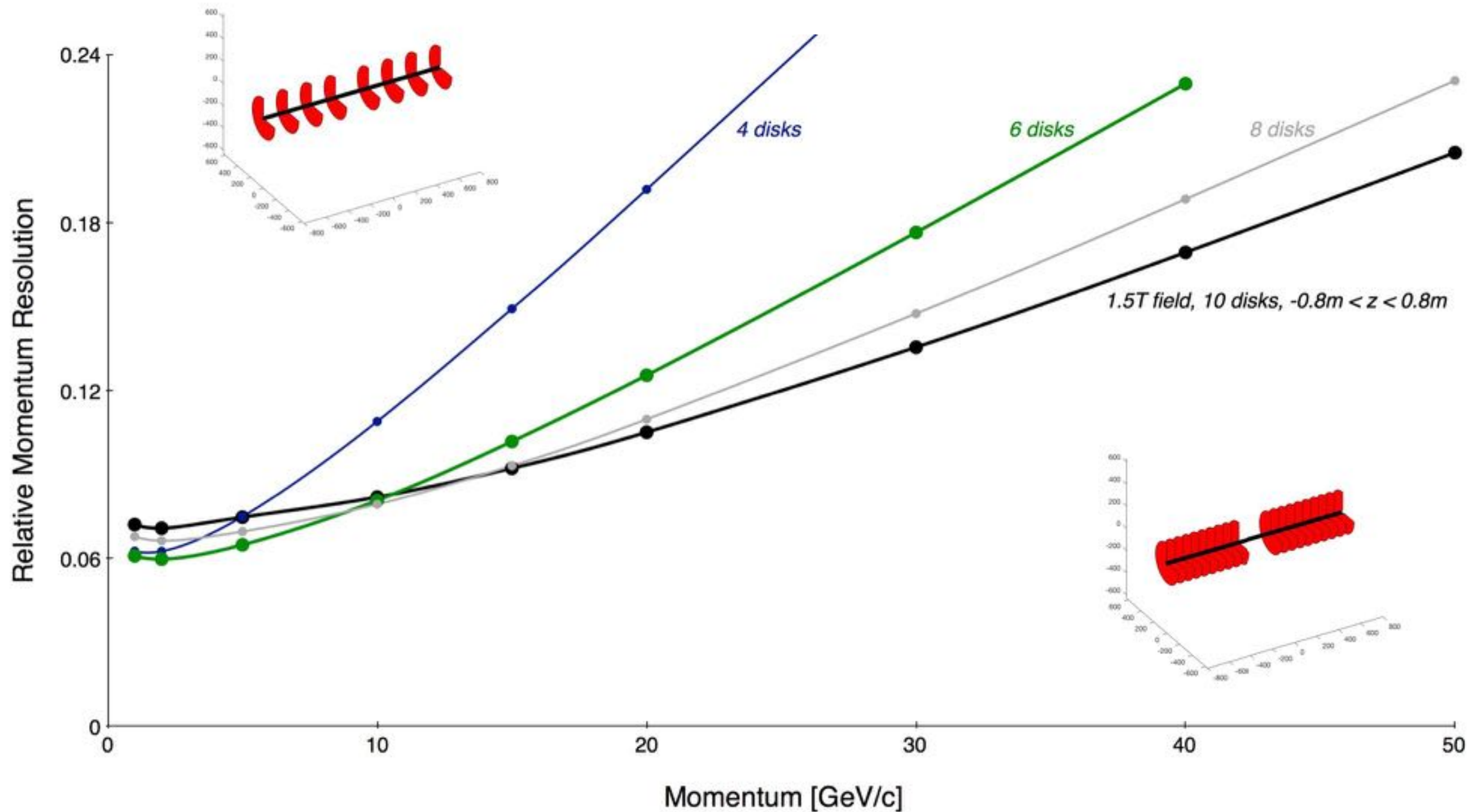
Anticipated behavior for large momenta; a larger number of disks results in better resolution. At lower momenta, the lower material budget of a smaller number of disks results in better performance. Geometrical effects play a role as well (e.g. inner radius)

Simulations - Disk Configuration

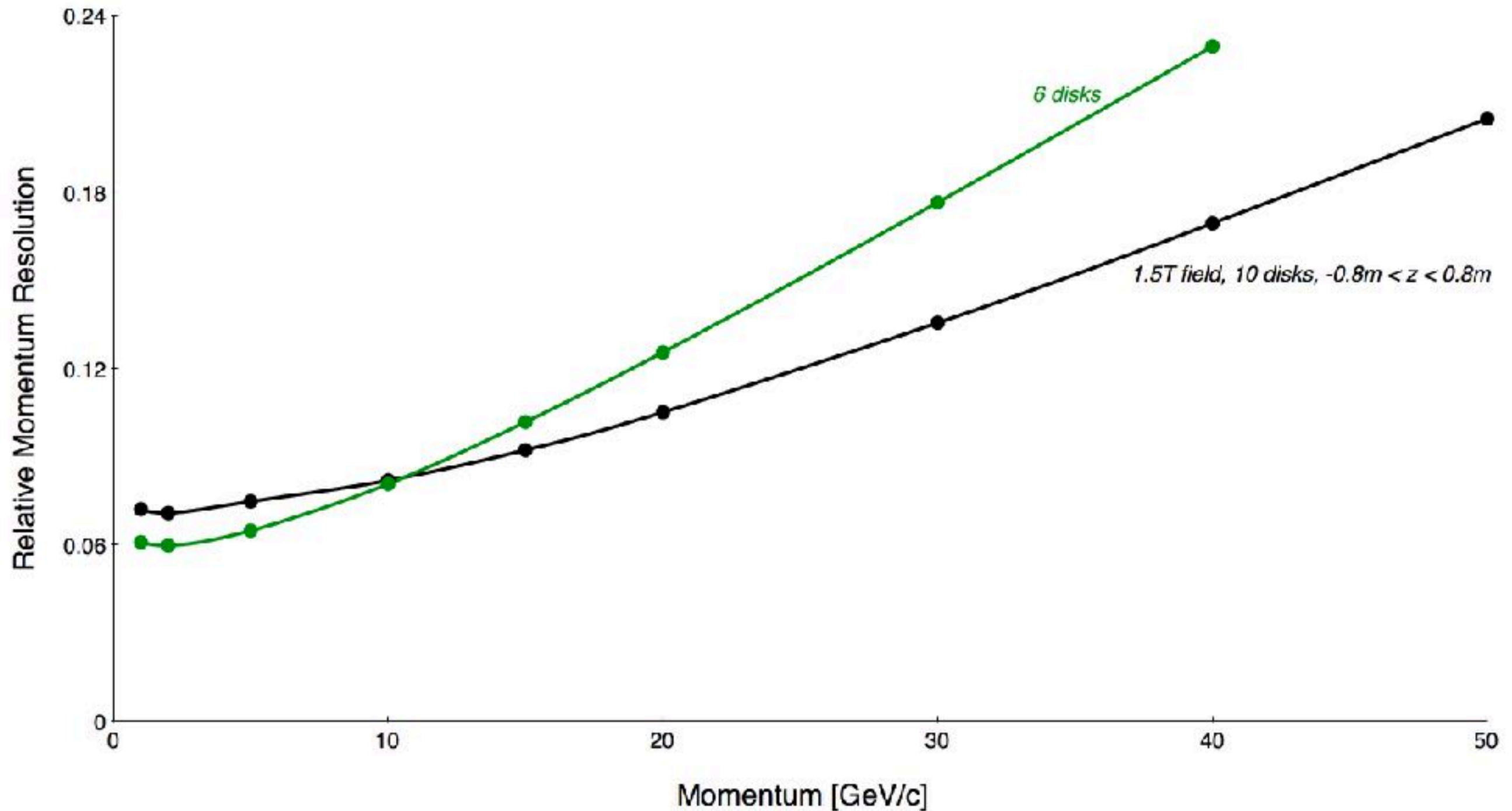


- Momenta in the forward electron direction are typically lower than in the forward hadron direction,
- Simulated momentum resolutions then suggest tracking concepts with different number of disks on either side of the IP,
- Qualitatively consistent with asymmetric implementation at HERA.

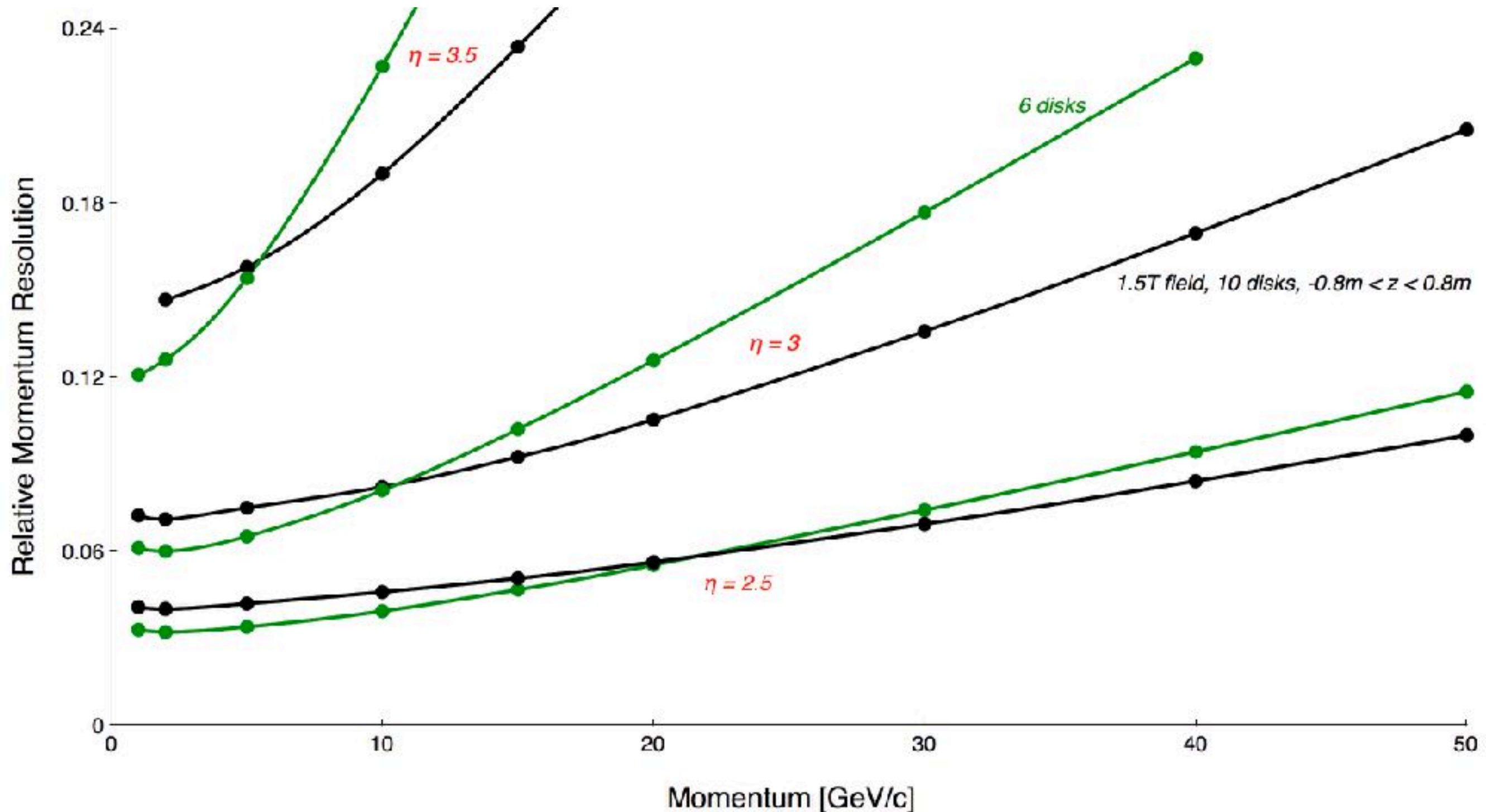
Simulations - Disk Configuration



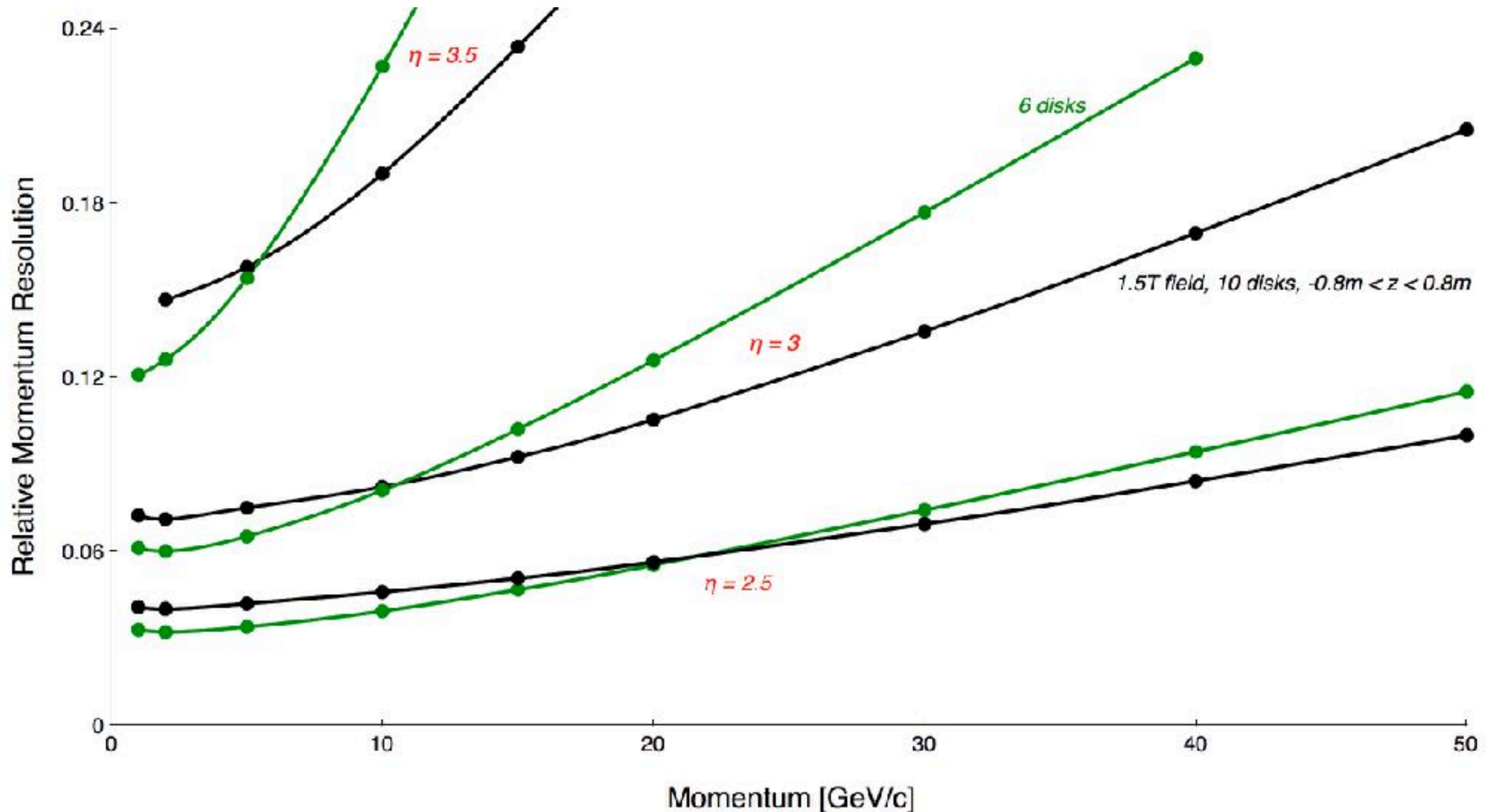
Simulations - Disk Configuration



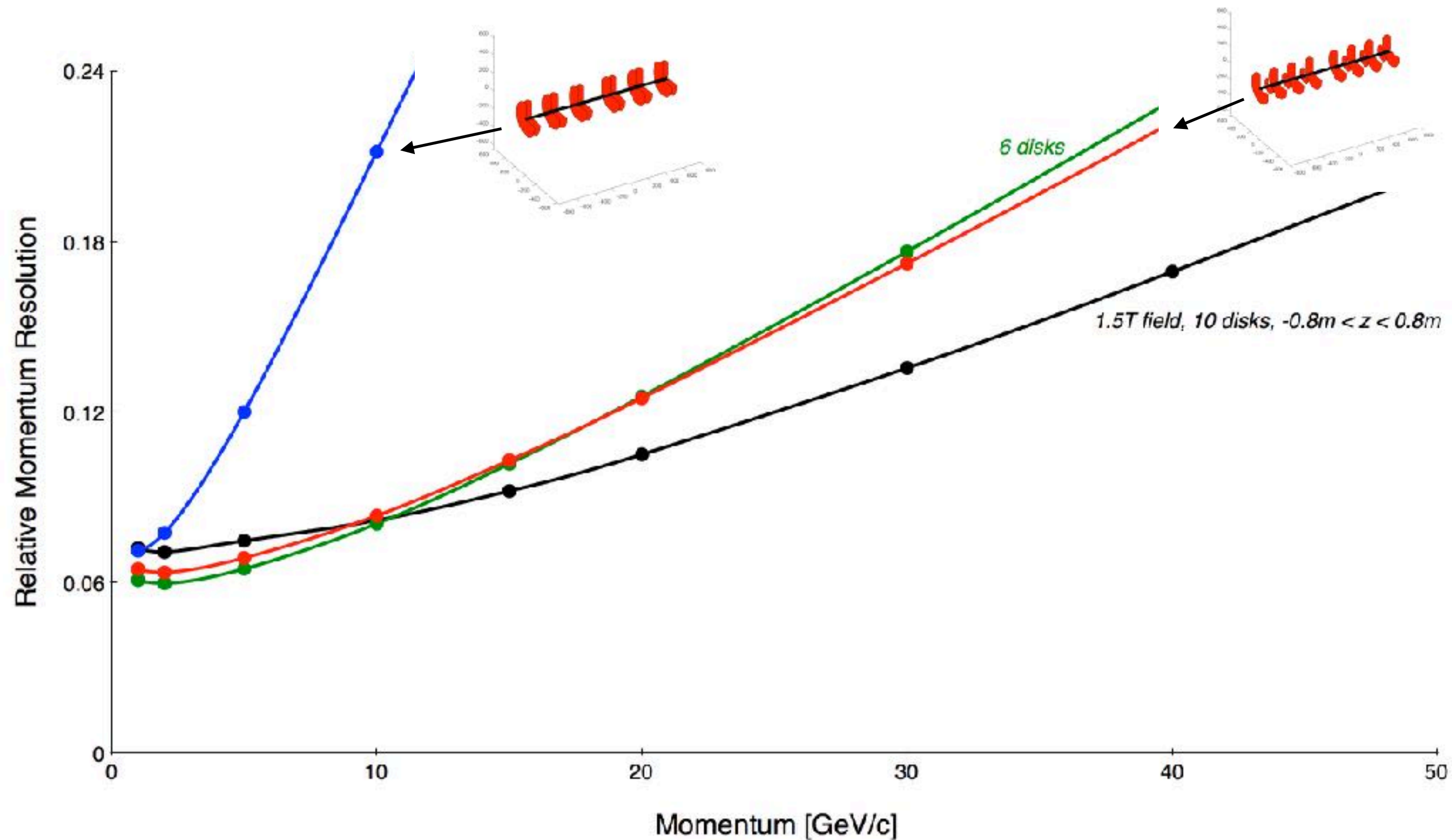
Simulations - Disk Configuration



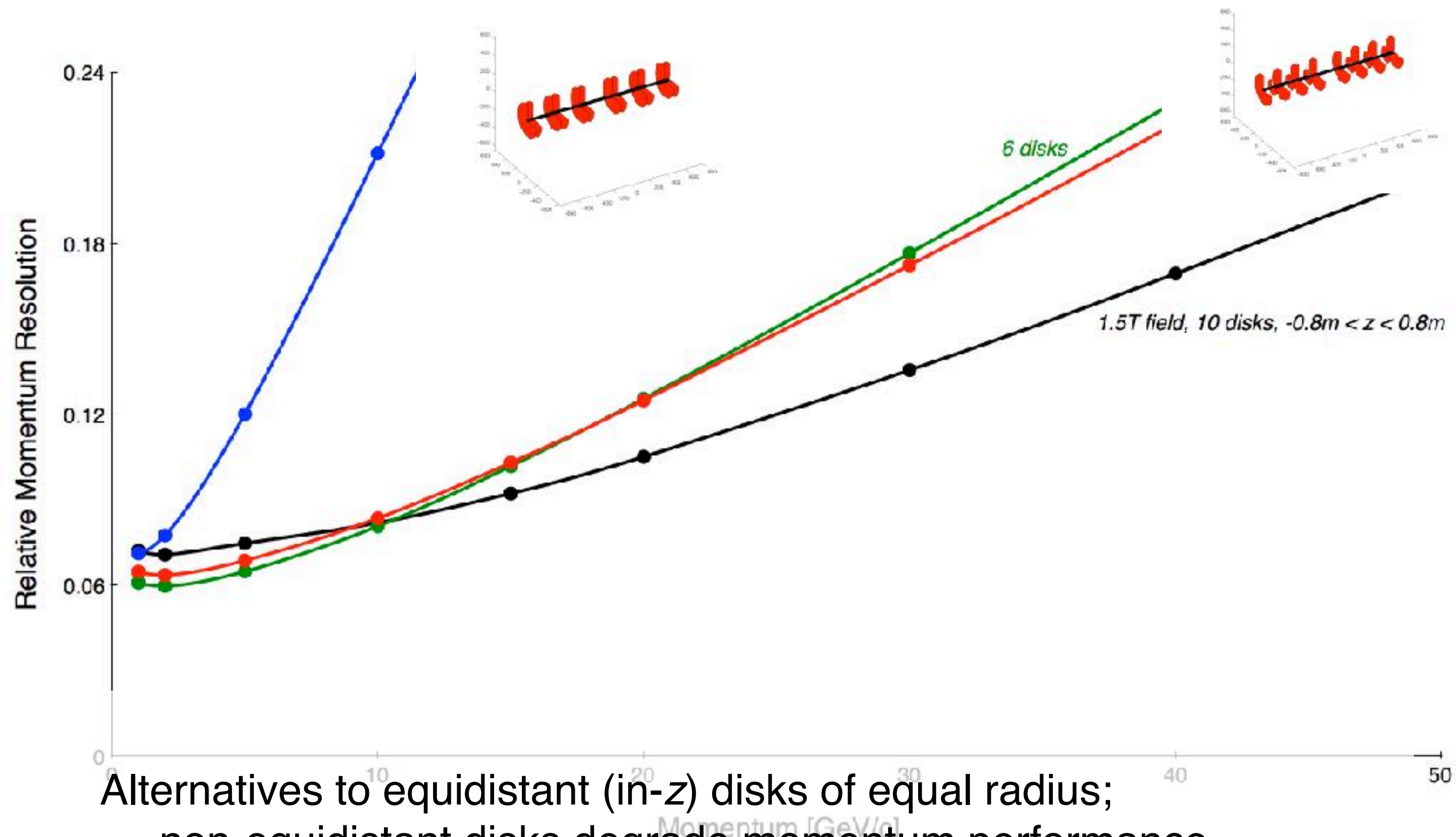
Simulations - Disk Configuration



Simulations - Disk Configuration

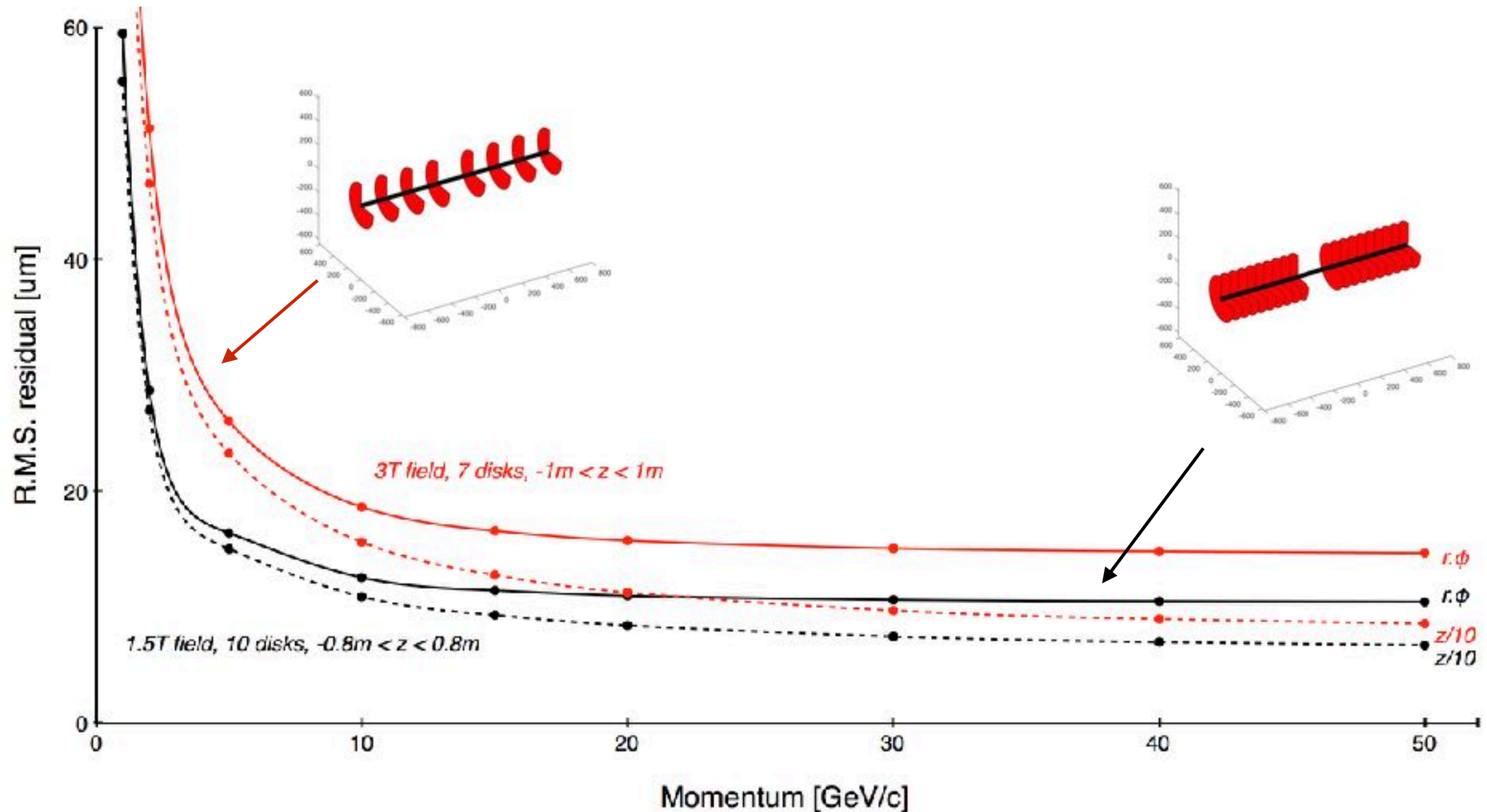


Simulations - Disk Configuration



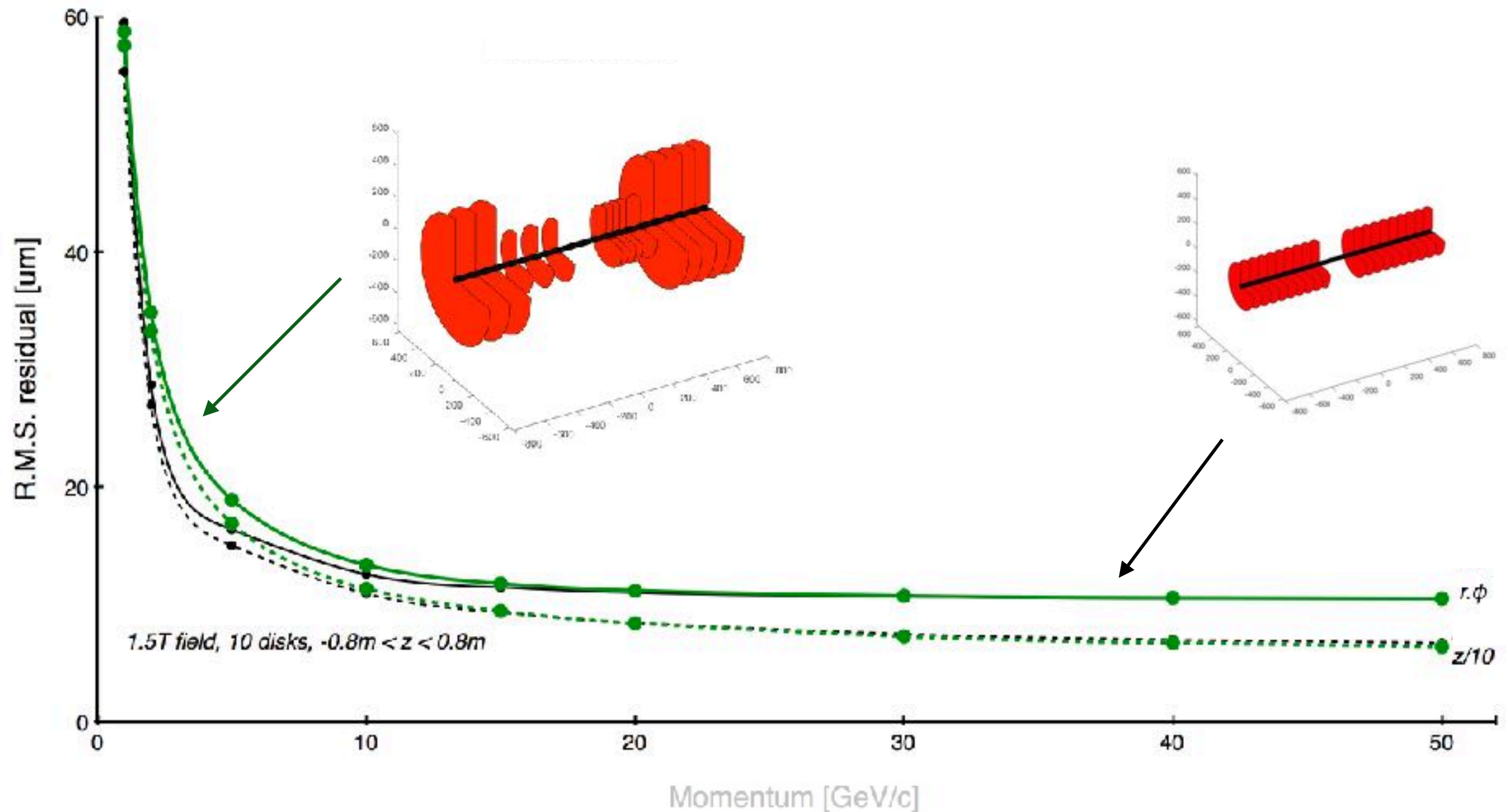
Alternatives to equidistant (in- z) disks of equal radius;
non-equidistant disks degrade momentum performance,
different radii may prove beneficial; will be considered further.

Simulations - Disk Configuration



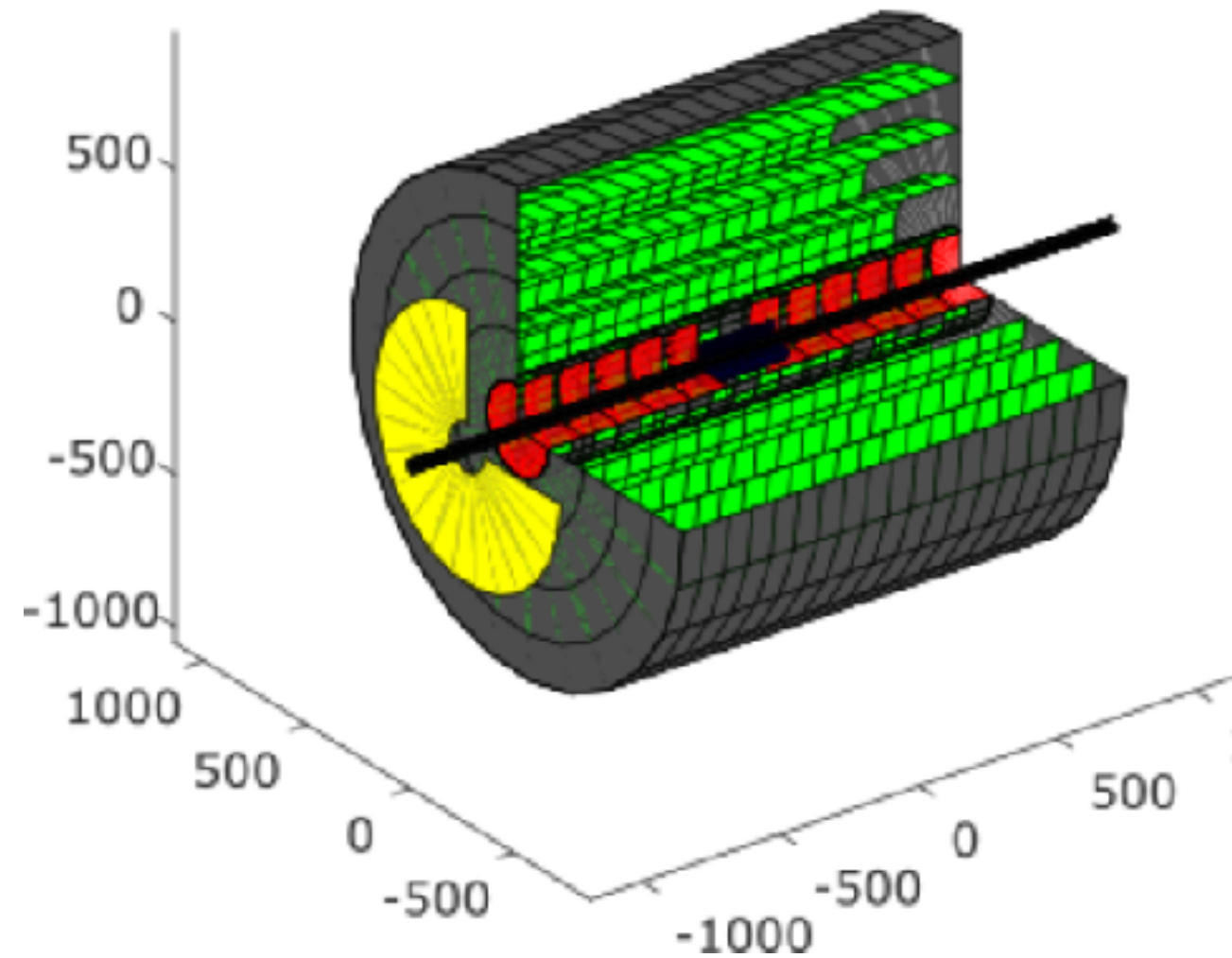
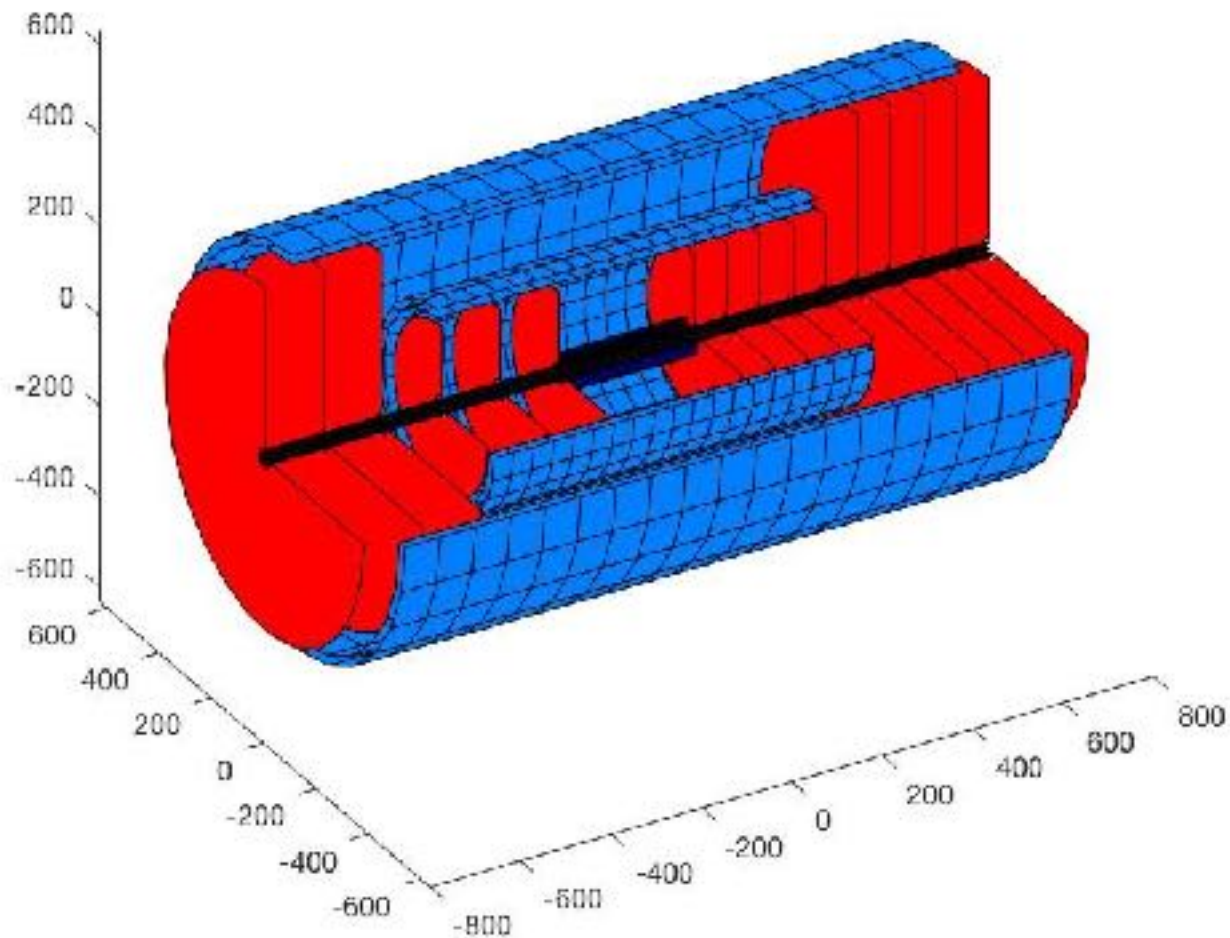
Alternatives to equidistant (in- z) disks of equal radius;
no apparent benefit either for pointing resolution
work on full-vertex reconstruction ongoing w. Michael Lomnitz

Simulations - Disk Configuration



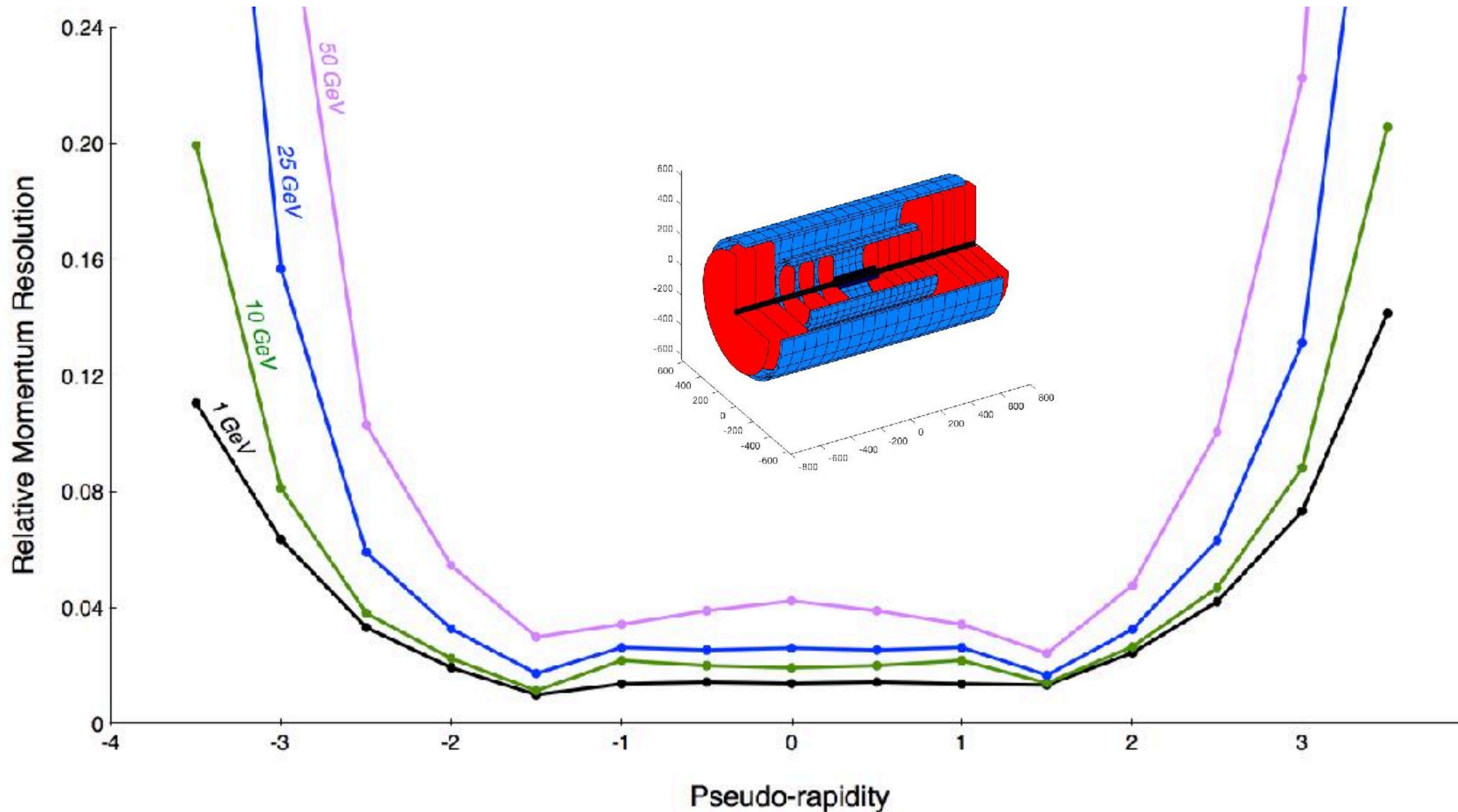
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Simulations - Combinations



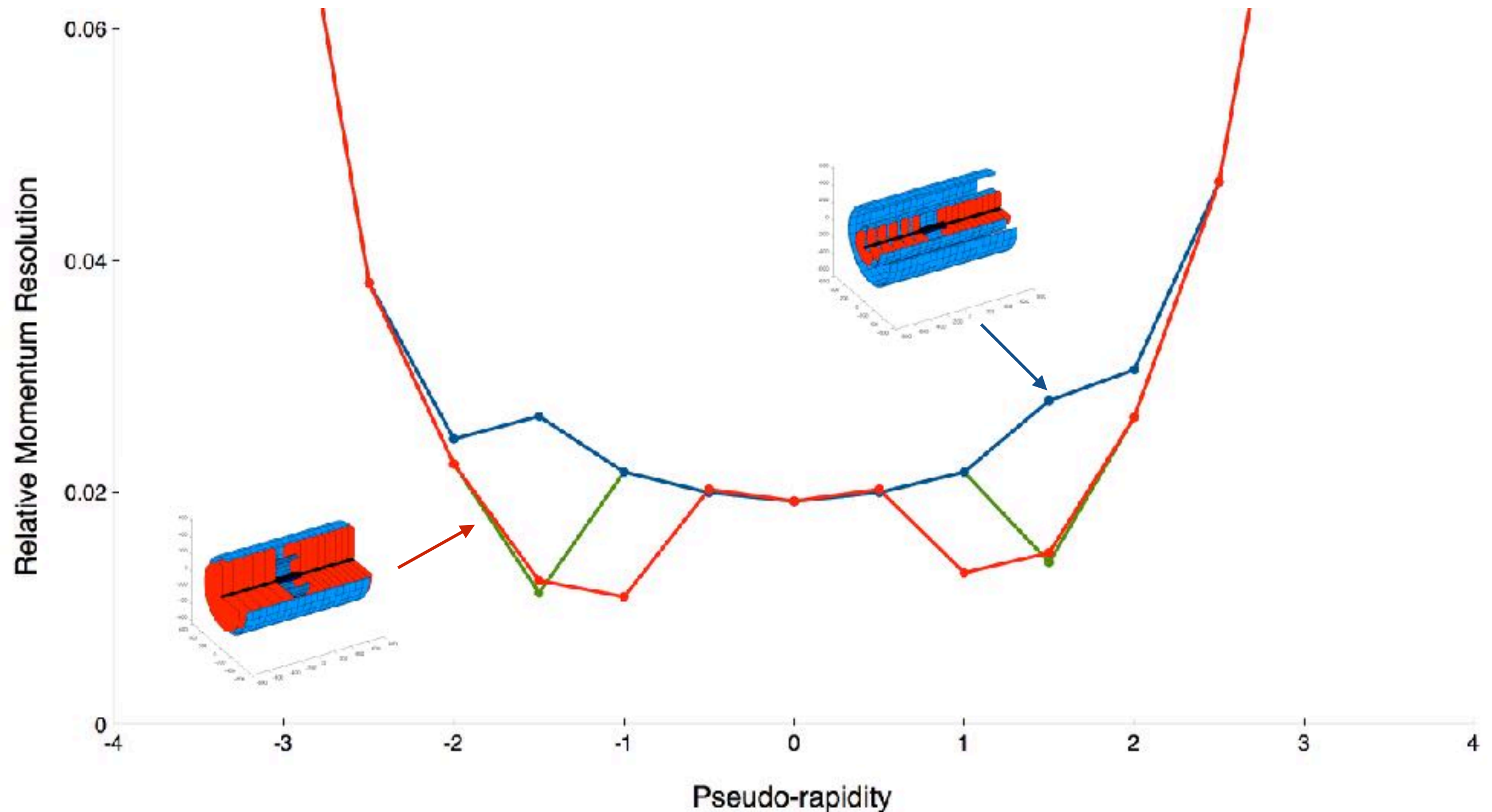
Initial steps towards integrating forward/backward disk-trackers;
Left: disks integrated with a 7-layer ALICE-ITS “copy”,
Right: barrel and disks as an inner-tracker to a TPC + GEMS disks.

Simulations - Combinations



A hypothetical all-Si tracker ($> 10\text{m}^2$) in a 1.5T Solenoidal field.

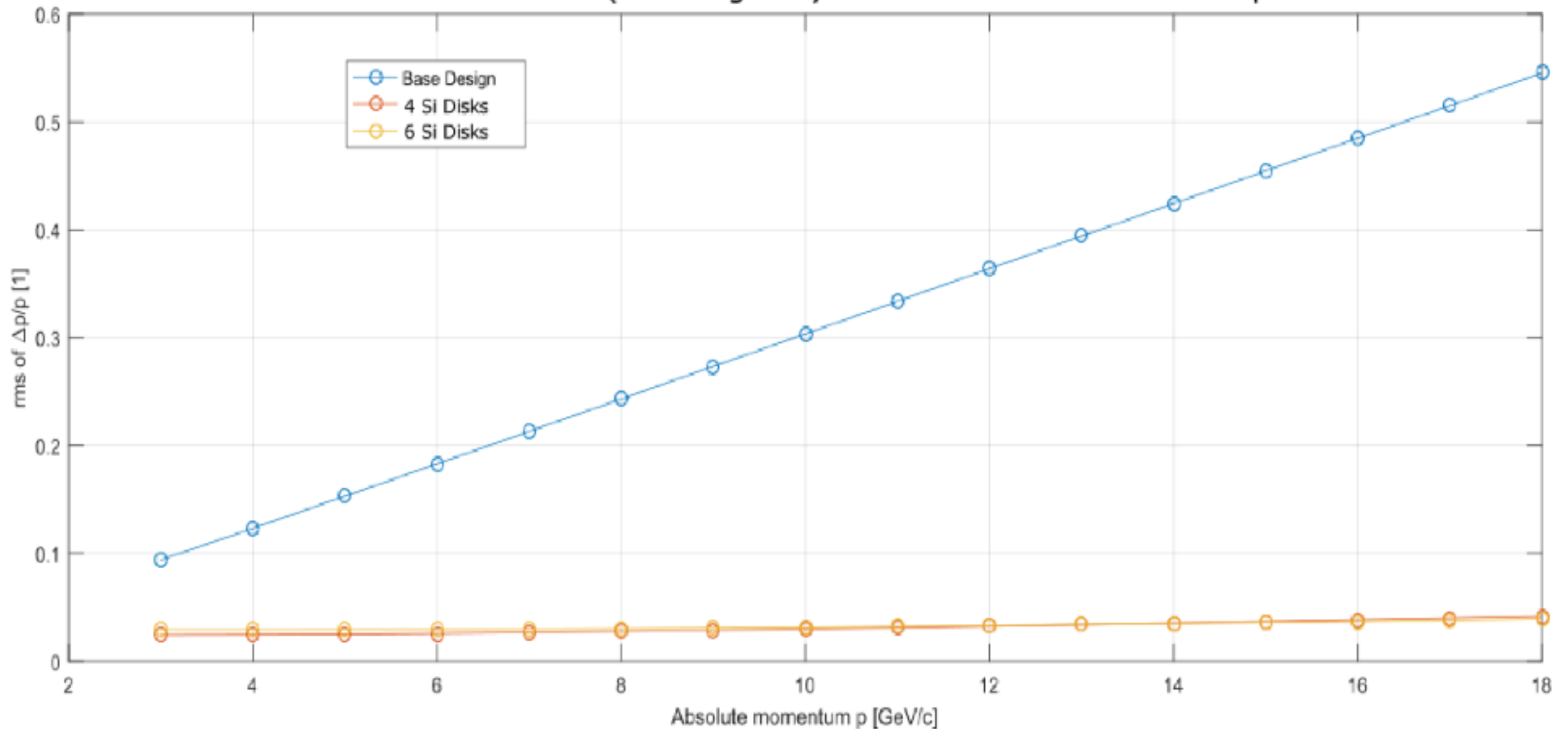
Simulations - Trade-offs Barrel/Disk



A hypothetical all-Si tracker ($> 10\text{m}^2$) in a 1.5T Solenoidal field.
Initial assessment of trade-off between barrel-length and disks with
new UCB student W. DeGraw and LBL postdoc M. Lomnitz

Simulations - Combinations

Forward Electron (170 Degrees) Momentum Resolution Comparison



A Si-tracker in the detector concept around the 1.5T BaBar magnet
with UCB student Ivan Velkovsky - ready for writeup,

Vast improvement over baseline design,

BeAST effort just started w. LBL postdoc Yue Shi Lai (EICRoot),
new UCB student Winston DeGraw (LiC tools)

Closing Comments

Sensor:

ALPIDE 28 x 28um pixel size adequate,
4us integration/rise time under study,

Configuration:

Optimization for momentum resolution leads
to a lower number of equidistant disks in
the forward-going electron direction,

Initial simulations show very limited gains from
non-equidistant disk configurations for single-track
pointing resolution,
full vertex reconstruction in progress

Disks with different radii will be studied further in light of services

Initial understanding of trade-offs between central barrel and forward disks,

UCB students have proven a very productive avenue

LBNL LDRD has made it possible to attract LBL postdoc M. Lomnitz who will pursue the
barrel region further at the level of 50% of his time,

BeAST simulations with EIC tools have just started w. LBL postdoc Y.S. Lai, LiC-tools W. DeGraw

Low-Mass conductors - will return in a future update.

